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**DEFUZZIFICATION OF GROUPS OF FUZZY NUMBERS  
USING DATA ENVELOPMENT ANALYSIS**



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## Abstrak

Penyahkaburan merupakan satu proses kritikal dalam pelaksanaan sistem kabur yang menukar nombor kabur kepada perwakilan rangup. Sebilangan kecil penyelidik telah memberikan tumpuan pada kes yang mana data rangup asal atau output rangup mesti memenuhi suatu set hubungan yang ditentukan dalam data rangup asal. Fenomena ini menunjukkan bahawa data rangup ini secara matematiknyanya saling bersandar antara satu sama lain. Tambahan pula, nombor kabur ini boleh wujud sebagai satu kumpulan nombor kabur. Oleh itu, tujuan utama tesis ini adalah untuk membangunkan satu kaedah yang menyahkabur kumpulan nombor kabur berasaskan model Charnes, Cooper, and Rhodes (CCR) – Analisis Penyampulan Data (DEA) dengan mengubah suai kaedah pusat graviti (COG) sebagai fungsi objektif. Kekangan mewakili hubungan pada output rangup dan beberapa sekatan pada output rangup yang dibenarkan bagi memenuhi sifat kebergantungan pada output rangup. Berbanding dengan kaedah asas pemrograman linear (LP), kaedah yang dinyatakan lebih cekap, dan mampu menyahkabur nombor kabur tak linear dengan penyelesaian lebih jitu. Kaedah penyahkabur asas CCR-DEA yang dicadangkan juga mampu untuk menyelesaikan nombor kabur tak linear dan memperoleh penyelesaian yang tepat. Selain itu, output rangup yang diperoleh melalui kaedah yang dicadangkan adalah titik terdekat bagi kes output rangup tidak bersandar, dan titik terdekat terbaik bagi titik terdekat bagi kes output rangup bersandar. Kesimpulannya, kaedah penyahkabur CCR-DEA boleh mencipta sama ada output rangup bersandar dengan mengekalkan hubungan atau output rangup tak bersandar tanpa hubungan. Selain itu, kaedah yang dibangunkan merupakan kaedah umum untuk menyahkabur kumpulan nombor kabur atau nombor kabur individu dengan andaian kecembungan bagi fungsi atau keahlian linear atau tak linear.

**Kata kunci:** Penyahkabur, Analisis penyampulan data, Kumpulan nombor kabur, Output rangup bersandar, Output rangup tak bersandar.

## Abstract

Defuzzification is a critical process in the implementation of fuzzy systems that converts fuzzy numbers to crisp representations. Few researchers have focused on cases where the crisp outputs must satisfy a set of relationships dictated in the original crisp data. This phenomenon indicates that these crisp outputs are mathematically dependent on one another. Furthermore, these fuzzy numbers may exist as a group of fuzzy numbers. Therefore, the primary aim of this thesis is to develop a method to defuzzify groups of fuzzy numbers based on Charnes, Cooper, and Rhodes (CCR)-Data Envelopment Analysis (DEA) model by modifying the Center of Gravity (COG) method as the objective function. The constraints represent the relationships and some additional restrictions on the allowable crisp outputs with their dependency property. This leads to the creation of crisp values with preserved relationships and/or properties as in the original crisp data. Comparing with Linear Programming (LP) based model, the proposed CCR-DEA model is more efficient, and also able to defuzzify non-linear fuzzy numbers with accurate solutions. Moreover, the crisp outputs obtained by the proposed method are the nearest points to the fuzzy numbers in case of crisp independent outputs, and best nearest points to the fuzzy numbers in case of dependent crisp outputs. As a conclusion, the proposed CCR-DEA defuzzification method can create either dependent crisp outputs with preserved relationship or independent crisp outputs without any relationship. Besides, the proposed method is a general method to defuzzify groups or individuals fuzzy numbers under the assumption of convexity with linear and non-linear membership functions or relationships.

**Keywords:** Defuzzification, Data envelopment analysis, Groups of fuzzy numbers, Dependent crisp outputs, Independent crisp outputs.

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## List of Abbreviations

A&H	Abbasbandy & Hajjari's (2009) method
A&Z	Asady & Zendamman's (2007) method
AHP	Analytic Hierarchy Process
AP	Andersen and Petersen Model
BCC	Banker, Charnes and Cooper Model
CCR	Charnes, Cooper and Rhodes
CCR	Charnes, Cooper and Rhodes Model
COA	Center of Area method
COG	Center of Gravity method
CRS	Constant Returns-to-Scale
CV index	Coefficient of Variation method
DEA	Data Envelopment Analysis
DM	Decision-Maker
DMU	Decision Making Unit
DRS	Decreasing Returns to Scale
FCCR	Fuzzy Charnes, Cooper and Rhodes Model
FDH	Free Disposal Hull
FGP	Fuzzy Goal Programming
FIME	Fuzzy Input-Mix Efficiency
FIW	Fuzzy Interval Weight
FLP	Fuzzy Linear Programming
FSBM	Fuzzy Slacks-Based Measure
Fuzzy DEA	Fuzzy Data Envelopment Analysis
FWGP	Fuzzy Weighted Goal Programming
GP	Goal Programming
HM	Height Method
HTF	Hospital Tuanku Fauziah
IME	Input-Mix Efficiency
IRS	Increasing Returns to Scale



IW	Interval Weight
IWGP	Interval Weight Goal Programming
LGP	Lexicographical Goal Programming
LP	Linear Programming
MADM	Multiple Attribute Decision Making
MAJ	Mehrabian, Alirezaee, and Jahanshahloo
Max	Maximum
MCDA	Multi Criteria Decision Analysis
MCDM	Multi Criteria Decision Making
Min	Minimum
MODM	Multi-Objective Decision Making
MOH	Ministry of Health
MOLP	Multi-Objective Linear Programming
MOMP	Multi-Objective Mathematical Programming
MOP	Multi-Objective Problem
MPI	Malmquist Productivity Index
NDRS	Non-Decreasing Returns to Scale
NIRS	Non-Increasing Returns to Scale
NLP	Non-linear Programming
OR	Operation Research
PPS	Production Possibility Set
SBM	Slacks-based Measure (SBM)
TpFN	Trapezoidal Fuzzy Number
TrFN	Triangular Fuzzy Number
VRS	Variable Returns to Scale
WAM	Weighted Average Method
WEI	Without Explicit Inputs
WEO	Without Explicit Inputs
WGP	Weighted Goal Programming

# **CHAPTER ONE**

## **INTRODUCTION**

In the theory of classical set, two alternatives are allowed for an element i.e. it either should strictly be a member of a set or should not. The fuzzy set concept developed by Zadeh in 1965, along with its techniques, is an interesting and promising approach to address complex, real-world issues with a new pattern for modelling human logic to improve a simplification model. As a result, more robust and versatile models have been developed (Lai & Hwang, 1992).

### **1.1 Fuzzy System Structure**

The term ‘system’ is defined as an ordered structure containing interdependent and interrelated elements (factors, entities, components, etc.). These elements frequently affect each other (in a direct or indirect way) for the system to exist, maintaining their activity and achieving the system goal. All systems consist of outputs, inputs, mechanisms, and boundaries which are usually identified by the system observer (Huang & Shi, 2002). However, the precise mathematics or crisp representation for modelling a complex system is insufficient due to the imperfect information and knowledge (Sladoje, Lindblad, & Nyström, 2011). Hence, the ‘fuzzy system’ term could be used in labeling any classification that has a structure and mechanism based on the fuzzy theory (Starczewski, 2013).

In general, a fuzzy representation provides more information about a set than a crisp representation. To replace a crisp representation of sets with a fuzzy representation in fuzzy system applications, the process of fuzzification is applied. As the objective

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